Purpose: To develop and evaluate a methodology for using hybrid MV-kV imaging technique for real-time respiratory motion tracking during arc therapy with minimized extra imaging dose while maintaining high 3D targeting accuracy.

Methods: In our method, at the beginning 4 seconds of a typical arc delivery for tumors in the thoracic and abdominal region, the implanted marker positions are measured continuously using stereoscopic MV-kV imaging. At later times, only treatment-beam cine-MV images are acquired. The 3D time-varying marker positions are estimated by combining the 2D projection data and the correlative relationship between the directional components of marker motion established from stereoscopic imaging, with the constraint that the position minimizing the distance to the first principal component line segment is the most likely position. A multivariate linear regression method is used to predict the marker positions 310 and 460 ms in the future. To evaluate the proposed method, computer simulations were performed using over 70 hours of thoracic and abdominal tumor motion data from 46 patients. A Gaussian noise with zero mean and 0.5 mm standard deviation was added to the projected marker positions on the imagers to simulate the system calibration and marker detection errors.

Results: The average RMS error of the 3D position estimation was 0.76 mm. At a 310 ms latency, the average overall RMS positioning accuracy was 1.23 mm. At a 410 ms latency, the error increases to 1.46 mm. Because the kV imaging is only used for a short period of time, the extra patient dose from imaging in IGRT can be reduced for at least an order of magnitude.

Conclusions: The proposed clinically-ready hybrid MV-kV imaging method incurs minimal imaging dose to the patient as compared with other stereoscopic imaging techniques because of an informed exploitation of "dose-free" cine-MV imaging without sacrificing targeting accuracy.